

Claims

1. A method of growing an essentially perfect colloidal photonic crystal exhibiting a single face-centred-cubic structure comprising the steps of :-
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- i. preparing a suspension of monosized colloidal spheres (1) having a volume concentration that produces spontaneous local crystallisation in a suitable dispersion medium,
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- ii. inserting the colloidal suspension into a gap between two substantially parallel surfaces (2,3),
- iii. subjecting the surfaces to relative oscillating motion (5) parallel to their surfaces and,
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- iv. subjecting the surfaces to a series of small linear displacements (6) relative to each other, the displacements being parallel to their surfaces and in two dimensions, comprising the sequence of applying a linear displacement to one of the surfaces with respect to the other surface,
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- rotating the direction in which the linear displacement is applied to the surface by substantially 120 degrees in a single constant direction and applying a further linear displacement to the surface, the sequence being repeated until the colloidal photonic crystal has been purified into a single face-centred-cubic structure.
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2. A method according to claim 1 wherein the dispersion medium is changeable from a liquid phase to a solid phase in order to fix the colloidal crystalline structure.

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3. A method of growing an essentially perfect colloidal photonic crystal exhibiting a single face-centred-cubic structure comprising the steps of :-
- 5 i. preparing a suspension of monosized colloidal spheres (1) having a volume concentration that produces spontaneous local crystallisation, in a dispersion medium that is changeable from a liquid phase to a solid phase in order to fix the colloidal crystalline structure
 - 10 ii. inserting the colloidal suspension into a gap between two substantially parallel surfaces (2,3), and
 - iii. subjecting the surfaces to relative oscillating motion parallel to their surfaces (5).
- 15 4. A method according to any of the preceding claims wherein the magnitude of the small linear displacements applied to the surfaces is substantially equal to the product of the diameter of the colloidal spheres and the number of crystalline layers in the crystal.
- 20 5. A method according to claim 1 or 2 wherein the surfaces are displaced with respect to each other in an equilateral triangle.
6. A method according to any of the preceding claims wherein the minimum volume fraction of monosized colloidal spheres is 0.49
- 25 7. A method according to any of the preceding claims wherein the radius of the monosized colloidal spheres is in the range 0.01 μ m to 100 μ m.
8. A method according to any of the preceding claims wherein the radius of the monosized colloidal spheres is in the range 0.05 μ m to 10 μ m.
- 30 9. A method according to any of the preceding claims wherein the material used for the colloidal spheres is at least one of a polymer, a non-linear material, a magnetic

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material, a metal, a semiconductor, glass doped with an active dye, polymer doped with an active dye, silica.

10. A method according to claim 9 wherein the colloidal spheres are
5 polymethylmethacrylate.
11. A method according to claim 1 wherein the material used for the dispersion medium is at least one of an adhesive, a polymer, a resin, a non-linear optical material, an active optical material, octanol.
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12. A method according to claim 11 wherein the active optical material used for the dispersion medium is a liquid crystal material.
13. A method according to claim 1 wherein the dispersion medium is subsequently
15 removed from the colloidal photonic crystal to leave a structure comprising colloidal spheres surrounded by an interconnecting matrix of voids.
14. A method according to claim 13 and further comprising the subsequent step of introducing a substitute material into the interconnecting matrix of voids
20 surrounding the colloidal spheres.
15. A method according to claim 14 wherein the substitute material is at least one of a metal, a semiconductor, a non-linear optical material, an active optical material.
- 25 16. A method according to claim 15 wherein the substitute active optical material is a liquid crystal material.
17. A method according to claim 15 and further comprising the subsequent step of removing the colloidal spheres from the substitute material.
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18. A method according to claim 12 or 16 and further comprising the step of adding to the colloidal photonic crystal means for applying an electric field to the liquid crystal material.
- 5 19. A method according to any of claims 2 - 10 wherein the material used for the dispersion medium is at least one of an adhesive, a polymer, a resin.
20. A method according to claim 1 or 19 wherein the dispersion medium is an epoxy resin and further comprising the subsequent step of curing the resin to form a solid
10 interconnecting matrix between the colloidal spheres.
21. A method according to claim 20 wherein the curing process includes at least one of exposure to electromagnetic radiation, exposure to ultraviolet radiation, chemical reaction, elevation of temperature.
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22. A method according to claim 2 or 3 wherein at least one of the substantially parallel surfaces (2,3) comprises a substantially flexible membrane.
23. A method according to claim 2, 3 or 22 wherein the series of small linear
20 displacements (6) is applied to the surfaces by rolling means (30,31) to produce bulk colloidal photonic crystal film (37).
24. A method according to claim 2 or 3 and further comprising the intermediate step of applying a detachable membrane to the internal face of at least one of the parallel
25 surfaces prior to introducing the colloidal suspension.
25. A method according to any of the preceding claims wherein the internal surface of at least one of the parallel surfaces is textured to promote the growth of multiple crystal domains.
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26. A method according to any of the preceding claims wherein the refractive index of the dispersion medium is substantially different from the refractive index of the colloidal spheres.

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27. A method according to claim 26 wherein the refractive index ratio between the colloidal spheres and the dispersion medium is greater than two.
28. A method according to claim 2 or 3 and further comprising the subsequent step of
5 removing the colloidal spheres from the solidified dispersion medium.
29. A method according to claim 28 and further comprising the subsequent step of introducing a substitute material into the voids in the solidified dispersion medium.
- 10 30. A method according to claim 29 wherein the substitute material is at least one of a non-linear optical material, an active optical material or a laser dye.
31. A method according to claim 1, 2, or 3 wherein the two surfaces are concentrically cylindrical (20,21).
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32. An essentially perfect, single face-centred-cubic colloidal photonic crystal produced by the method of any of the preceding claims.
33. An optical notch filter having a colloidal crystal according to claim 32 wherein the
20 colloidal sphere radius and refractive index of the dispersion medium are selected to co-operate to reflect at least one specific wavelength and to transmit other wavelengths.
34. An optical device having a colloidal crystal according to claim 32 and further
25 comprising
- a liquid crystal material, and
- means for applying an electric field to the liquid crystal material
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- wherein a variable voltage is applied to the liquid crystal material to change the refractive index contrast between the liquid crystal material and the colloidal spheres.